Knowledge management for industrial heritage

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Abstract

All along history, humans have always invented, created to improve their standard of living. Many machines have been built, sometimes simple and others very complex.
In order to achieve the best results for customers, machines, industrial plants and humans are moved, displaced and replaced. It is the global humanity technical knowledge that disappears.
Indeed, there is a lack in the actually conservation methods: sciences and technologies have to be considered and not only architecture. Our heritage research focuses on the mechanical and technical point of view. For instance, in a factory, there is the building but also actuators, motors and machines that produce product: taking into account the technical point of view can reach to a better understanding of the past.
That's why preserving the national technical patrimony has now become the priority of governments and world organizations. Our approach proposes a new kind of finality: as saving and maintaining physical object cost a lot for museums, and sometimes dismantling is impossible as the machine falls in ruin, we propose to preserve it as a numerical object.
The aim of this research is to define the global process and technologies used for implementing a numerical model of old machines. The final aim is to constitute a new reference for museologic actors, using actual techniques and methods for putting old machines and technical means in "virtual use", taking into account the working situation including human being at work.
This process is illustrated by an example we performed: a steam engine.

Keywords

Knowledge Management, Reverse Engineering, Technical Heritage, Industrial archaeology

1. Introduction

All along past centuries, humans have always invented, created so as to improve their standard of living. Many machines have been built, from the very simple ones up to very complex ones.

In order to achieve the best results for customers, machines, industrial plants and humans are moved, upgraded and replaced. When out of operation, industrial machines are generally destroyed and sometimes, they are stored and collected by Museums.

Nevertheless, preserving the national technical heritage is now becoming a priority for governments and world organization. We will explain this point of view in the section 2.1.

This knowledge, testimony of the past, raises questions regarding its management and the valorization of the museums and the industrial plants: how to preserve the technical information contained in the collections, the files and the heritage plants [1]?

More and more, Knowledge Management is applied by enterprises in a nearly systematic way:

- tools and methods exist but questions still exist for technical history?
- which methods for capitalizing this knowledge?
- what kind of old technical should we have to conserve?

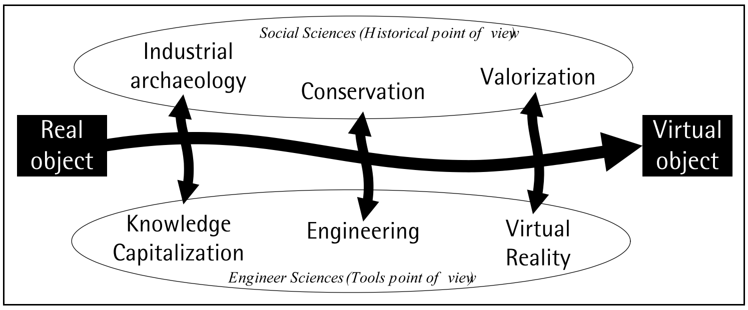

Fig. 1 - Methodology macroscopic model

Understanding an old technical machine can be easy to achieve for former workers or for a museum conservative but at the opposite its popularization can be difficult and highly delicate.

Considering that saving and maintaining physical objects is very costly for museums, and sometimes dismantling is nearly impossible as the machine crumbles to dust, our approach proposes a new kind of finality: we propose to preserve it as a numerical object.

In the first part of this communication, the research context is explained. It demonstrates how two scientifical domains can merge: Engineering science & Social science; thus, for one side according to Industrial Manufacturing & Design and on the other side Technical history. Next, the methodology developed for virtualizing technical machine and its environment is detailed. As shown by figure 1 which is a macroscopic overview, the final step of the methodology consists in conserving and vulgarizing the numerical model. All along the methodology description, an example is used so as to illustrate the global process.

2. Background

Before explaining the methodology, it is essential to consider the background of the research project and the way it was born. After identifying the conservation need, we try to point out why there is a lack in the actually conservation methods: sciences and technologies have to be considered and not only architecture. For instance, in a factory, there is the building but also actuators, motors and machines that produce product: taking into account the technical point of view can reach to a better understanding of the past. More, experiences individually done do not emphasize dynamic concepts of old machines: manufacturing a product means there are mechanical kinematics and processes. That's why merging engineering sciences and social sciences can be profitable for each one.

2.1 The idea birth

The protection of scientific, technical and industrial heritage is a relatively recent idea. It is in England, in the Sixties, that was born what British people call the "industrial archaeology".

The first experimentation object for the capitalization and the valorization of the heritage was the Ironbridge (this one was the first iron bridge, built in 1779 and classified to the world heritage of UNESCO in 1986 [2]). In his PhD related to the Seguin family history, Michel Cotte, technical history professor, introduced the concept of systemic objects for modeling processes... [3]. This approach, already strongly exploited in the Engineer Sciences, is not yet anthropocentered as it would be in Social sciences. Consequently, merging the two communities can enrich semantic and can create new methodologies.

For example, coming from the Social sciences, the methodology called "systemic" applied to old technical objects demonstrates the genetic of an object: who are the parents and the children, reasoning in term of technology? This approach is the same one called MKSM method based on the historical model, the lines model and the antagonists model [4]; MKSM was developed by Engineering sciences and is used as a method for capitalizing knowledge.

It is in this context that the subject of this research was born. After several experiments on old industrial objects, it has appeared that the conservation of the technical heritage encounters several major difficulties issued mainly from:

- a no-sensitizing of industrial world regarding the value of their technical heritage and the interest about the possibilities of heritage backup;
- financial difficulties to conserve, to maintain and to ensure the transportation of large size objects;
- a human difficulty due to the lack and the loss of the users consciousness and/or the disappearance of the machine manufacturers.

2.2 The world heritage conservation: what about sciences and technologies?

According to what is said in the previous section, there is a real problem for capitalizing knowledge related to local heritage, national heritage, and more widely… international heritage. For a part, it was the mission given up to UNESCO in 1972 which convention clearly states three categories of knowledge considered as cultural heritage [5]:

- monuments: architectural works, monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and features combinations, which are of outstanding universal value from an historic point of view, art or science;
- groups of buildings: groups of separate or connected buildings which, due to their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, art or science;
- sites: works of men or the combined works of nature and men, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view.

In 2003, at the ICHIM conference, Jean-Pierre Dalbéra from the French culture and communication Ministry laid the stress of the need for a capitalization and a valorization of the French heritage [6]. Since this communication, many research programs have been started in France; among them, we can quote:

- GALLICA, digitalization and diffusion on the Web of books coming from the French National Library "François Mitterand";
- CNUM, digitalization and diffusion on the Web of books coming from the French National Science and Technology Academy "Musée des Arts et Métiers".

However, they are focused on historical documents, images, art objects or architectural monuments… The technical industrial heritage has not been targeted as a priority for conservation. Some attempts are carried out independently by conservatives and by the "Musée des Arts et Métiers". At the "Arts-et-Métiers" museum, valorization of the technical and scientist heritage is the priority since the law of 1792 related to the French heritage conservation.

Although other experiences in other domains usually use those tools (for example archaeology [7]); the proposed approach focuses upon science and technology. All the studied objects (and their context) come from industrial plants. Moreover, studies are focused on the technical and mechanical point of view.

Jocelyn de Noblet proposes to classify the technical objects, scientific objects and/or industrial objects according to three categories [8]:

- objects of daily life that we own;
- objects of daily life that we use but we do not own;
- objects we do not use and do not own but that are necessary for manufacturing and/or using for objects of everyday life.

Our research belongs to the third category: objects we do not use and do not own but that are necessary for manufacturing and/or using for objects of everyday life. Objects considered are testimonies of the past and that could have become leaders of an old star technology. Discovering old machines allow discovering old technical cultures.

2.3 The heritage valorization: what about dynamic?

Initiated in 1992 by the French culture and communication Ministry, the French research and technology Ministry and the French Education Ministry, the REMUS project was the first one that had developed interdisciplinary teams in order to find new solutions for the museology of sciences and technology. Several works and studies were finalized: the main point was to advise for using audio-visual technologies [9].

Many case studies have already been carried out but only in static situation: "3D". Taking into account time concept "t" will give kinematics that is necessary for creating dynamic situations. Modeling and re-designing "3D+t" models will constitute a new step for museology (see part 3.2).

But videos can not be as realistic as immersion system used for example in Virtual Reality Center. Consequently, more have to be done about simulations of mechanical kinematics, product flows, fluids… in order to re-create working situations.

Moreover, setting up a virtual dynamic situation can go further. The World fair of the 19th century has been a real progress star. It has been the place for theatre representations playing with restored machines, brushed machines, smoothed machines, nice machines, in the silence and the light of the big showrooms (see figure 2 and 3).

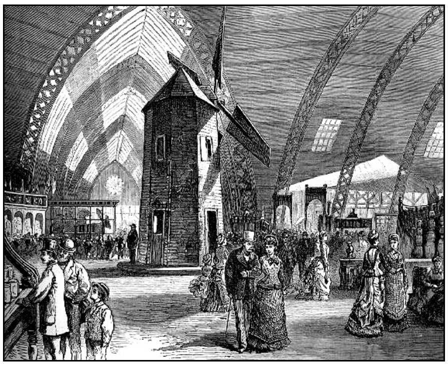

Fig. 2 - 1876 Philadelphia World exposition

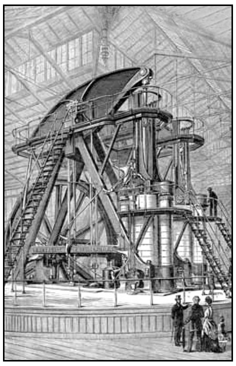

Fig. 3 - 1876 Philadelphia World exposition – The Corliss engine.

Nowadays, in Museums, "we are very far from the factory and the workshop, the noise and dust, tiredness and sweat, […] the violence of the social relationship which however contribute to the technologies history" as Paul Rasse said [10].

Conserving technical machines necessary means that the object has to be capitalized but also its mechanism operating by taking into account its technical and social context. Mechanically, operating is defined by functions and associated kinematics but also with process and used situation. Consequently, historical knowledge just like historical tools and methods are not enough for a complete understanding. Other knowledge has to be brought out.

2.4 The contributions of mechanical engineering and digital tools for Museums: a new way for the heritage valorization

Consequently, engineers and industrial engineering tools and methods can bring answers for capitalization, conservation and valorization of old machines.

Our proposition consists in reversing the design time axis from end of lifetime back to the initial need. Thanks to a re-design by modeling of the technical machines and a contextualization in its environment, then, it can be possible to restore it for multiple finalities and more widely to restore the working situation of the socio-technical production system [11]:

- control and measurement tools: from homemade measurement tools to laser scanning of the architects (systems with physical contacts, passive/active systems without physical contacts);
- design: from CAD tools to synthesis imagery;
- dynamic: technical machines with real kinematics with the representation of the flows, the fluids, the workers and the manufacturing environment;
- virtual visualization: from Web visualization to virtual reality;
- physical visualization: from the intermediate representation models of objects [12] thanks to rapid prototyping to a realistic and/or functional reconstruction of the machine.

Indeed, in France and all over the world, vulgarization experiences performed in Museums related to sciences and techniques usually refers to architecture plants or archaeological plants. The virtual technologies are used so as to create an imaginary world where the visitor can walk. The main objective is to give tools for a better understanding of the past: that's why colours are beautiful, and rendering is realistic… Although the virtual system creates interactions with the visitor, it presents only buildings and static old machines [13].

However, some Museums propose a new kind of use for virtual technologies: the "Virtual Visit". Nowadays, the most advanced country in the world that has virtualized all the museums is Canada. Using internet, it is possible to visit each Canadian museums. Moreover, all the sites are interconnected and switching from one museum to an other one can be done being at home. In 2004, the Canadian Heritage Information Network made a survey in order to know if the museum virtualization is useful [14]. The results demonstrate that it allows everybody to have access to knowledge. Among all the positive elements, we can notice that:

- it reduces the distance and allows people far away from Canada to visit Museums,
- it is accessible for handicapped,
- families can, at home, prepare their visit and their cultural holidays.

It is a new kind of publicity: communication is knowledge oriented. However, although web sites can interact with visitors, shown objects remain static.

Introducing new technology can be a real benefit both for visitors and for Museums. As usually, old machines do not operate or can not be exposed in the Museum, it can be a real and realistic new solution for capitalizing heritage. Globally, the problem of cost and security remains for preserving the machine functionalities: components wearing, the need of a machine driver… Consequently, using virtual technologies can be a real benefit for visitors and conservatives: Virtual Reality is a new mediation tool. On the opposite to videos and thanks to interactivity, it is easier to understand the operating situation: the visitor is no longer a spectator but an actor. As he is immersed in the system, he drives himself the virtual machine up to the possibilities to test the machine limits. Moreover, the mediation-tool detail level can be adapted by the conservatives to the targeted public.

2.5 Case studies and interest

The proposed model (see figure 5 in part 3) has been built thanks to experiences carried out during four years by French researchers. The first two studies began at the University of Technology of Belfort-Montbéliard (France), on a steam engine and a press.

Next, experiences were made up with students of the IUT de Nantes (France): in order to learn the use of CAO programs, it was decided to take as studied object an old printing machine coming from a museum (see figure 4) [15].

Nowadays, the team has accumulated other experiences that permit building the global process that will be used for capitalizing, digitalizing, modeling, conserving and valorizing old machines and associated knowledge in dynamic situation of use.

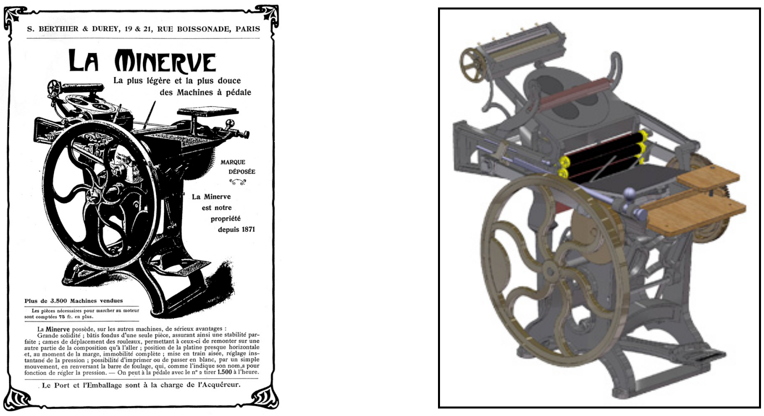

Fig. 4 - Printing press "La Minerve": manufacturer catalogue drawing & CAD model.

3. Process for a numerical heritage

3.1 Overview

Figure 5 presents the model we propose.

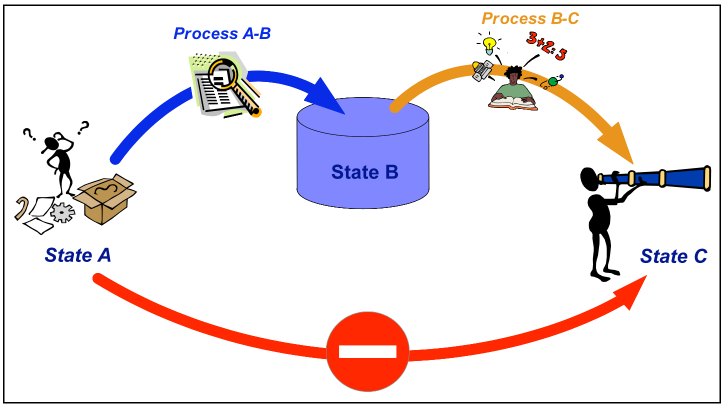

Fig. 5 - The global process for capitalizing and virtualizing old machines and associated knowledge.

State A is the starting point of the global process. It gives the statement of the object and its environment at the beginning of the conservation study. State A characterizes the object with its physical properties and the "outside world" as shown by Figure 6 as explained later in sections 3.2 and 3.3.

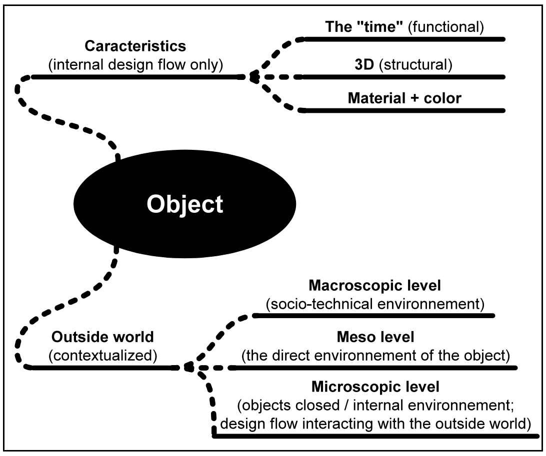

Fig. 6 - Physical object definition [16]

State C gives the various finalities of the valorization and conservation project.

State B is the necessary intermediate way for realizing State C. Whereas the direct way since the existing material data (State A) is not strongly advised as it will produce a non complete and realistic model of the object.

Then, State B is an essential intermediary step for a rigorous conservation method. For example, in case of museographic presentation of State C, if we intent to present virtually the object to public, only one part of the contents of the State B is used. In the same way, if it is used for a reconstruction of the object (that's means to recreate the machine), it will be another part of State B that will be taken into account.

To conclude, it is necessary to have the more complete and detailed State B since at the beginning of the process we generally do not know what kind of finalities (State C) it will be used for.

3.2 State A and process A-B: the object itself

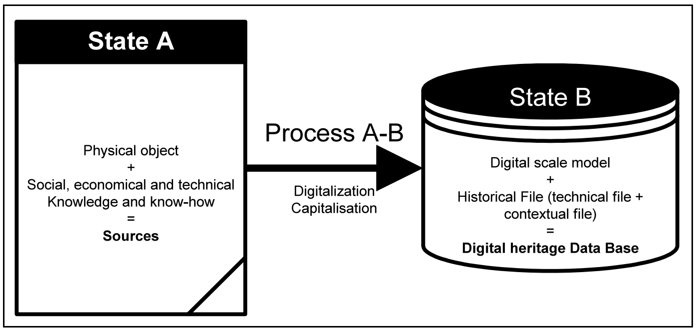

Fig. 7 - First step of the process: A to B

Determining the state of the object

The conservation method suggested will not consist first for restoring the object (see part 3.4, one possibility of the finalities). Process A-B consists in digitizing the object in order to immortalize it and to produce data that will be coherent, readable and transmissible to future generations.

At the beginning of the study, it must be determined and precise the object life period that has to be represented in the digitalization process and the modeling process:

- "new" object, in its initial state of first use;
- object in use with possibilities of including adaptations and innovations;
- object at the end of lifetime;
- object in its archaeological state of discovery or when it was decided to preserve it;
- object partially extrapolated according to the gaps of State A.

Digitalization

If the object exists partially or entirely at the time of the study, it is possible to digitize it directly in three dimensions in order to collect its geometry. Several solutions of digitalization exist: laser scanning, photogrammetry, measurement systems with contacts...

According to the size of the object, its materials nature and its degradation state, technologies used may be different.

If the object does not exist any more, thanks to external documents and knowledge, it will be possible to design an extrapolated model (see part 3.3).

Re-designing: static components

The digitalized dots obtained have to be treated in order to be able to design the various components of the object. Taking into account the file size and the wish to create a realistic model, we would prefer solid design instead of surfacing as we are speaking about mechanical parts.

Moreover, as modeling is costing a lot of time and money, it is necessary to specify the model accuracy level expected: screws, chamfers, precision for foundry parts… It is the same problem as encountered with over-quality in manufacturing processes.

Re-designing: dynamic functions

As used objects are not inert, they are animated by mechanisms that have to be virtually restored and simulated in order to validate operating [17].

In the first step of the process A-B, it is essential to produce a functional virtual model that is mechanically realistic and as accurate as possible. That's why using CAD programs is better than using CG programs (Computer Graphical). CG programs are usually used for creating animated pictures, movies… Indeed with CG programs, simulations and dynamic are not realistic as a "world" is created in which one the objects will move but this world does not have the properties of the terrestrial physical laws such as the fundamental principles of mechanics (the gravity for example). Indeed, the numerical mock-up will be realistic and not realist; but as realist as it can be [18]. Obviously, numerical files will never replace physical objects: it is only one way to represent reality.

Many experiences we did upon technical heritage have led us to the model shown on figure 8.

The physical object is separated into its 3D components, its skeleton and the concept "time". Time "t" will create the dynamic situation.

The methodology associated to figure 8 is:

1. an object skeleton has to be designed;
2. adding the concept of time, it will produce a kinematic sketch; drawn in 3D space, it will produce a wireframe that has to be iterated with the physical object in order to validate it and to fix the dynamic;
3. the last step will produce new knowledge maturation: the mechanism understanding;
4. next the dynamical digital model is created by anchoring solids on the skeleton.

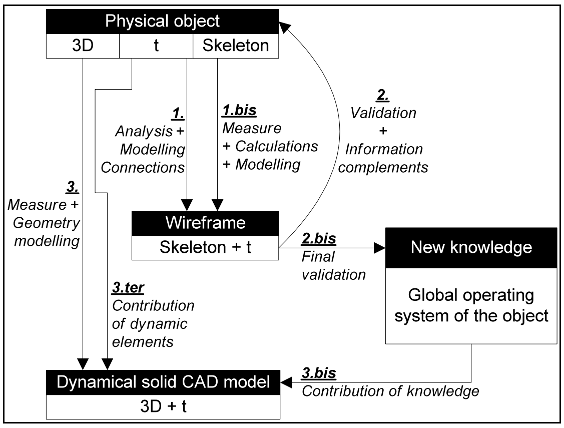

Fig. 8 - Method for modeling old systems

Environment and other dynamic flows

Except for kinematics, simulations are carried out in post-processing and without direct visualization. For example, this is a problem for modeling fluids: in the case of a steam engine, it is actually very difficult to visualize the exchanges of vapor. However, such visualization is essential for conservatives and all non-expert people.

It will also be necessary to consider the need of environment restitution: actuators and motors, the nearest machines, the industrial plant... do they have to be digitized, modeled?

Materials and other feelings

As seen before, an object is defined by its geometrical characteristics ("3D") and its kinematic functional properties ("3D+t"). But functionalities could also be due to the material properties used: then, it is necessary to carry out a virtualisation of materials.

In the same way, materials or paintings are design information that could be essential for a future restitution and that must be taken into account during the digitalization step.

Where are the limits of the external appearances in relation to the concept of authenticity? Is it necessary to restore false colors to prove the virtuality?

Speaking about design, an object can be characterized by its colorimetric but also by auditive and olfactive perceptions: how to capitalize sounds and odors in numerical form? Notice that those information's have sometimes disappeared with the dismantling or the non possibility of handing-over under operation of the machine.

3.3 State A and process A-B: the object and its context

As in archaeology (we think about excavations of archeological sites) the object gathers three ways: a genesis, a life and a place, and this, within a double approach: material and intellectual [19]. State A can not only be conserved by the physical object. That means that the object has to be contextualized by capitalizing the information, data, notes and know-how:

- at a technological and industrial level: in order to understand its operation and its insertion in the industrial plants;
- at a social and economic level: so as to contextualize the object in order to determine the technological developments.

This first step of taking into account the environment knowledge requires:

- the technologist know-how which knowledge capitalization methods are fully rising in industries;
- however, it is important to notice that it does not exist yet methods nor tools for capitalizing the environment of patrimonial objects;
- the competences of archaeologists and technical historians;
- however, it is also important to notice that a systematic method within a technical study framework does not exist.

Indeed, understanding and studying an old technical object requires a multiple jobs crossing and a large contextualisation. Consequently, we will have to consider many various sources. Here are some examples of sources:

- machine drawings published by manufacturers;
- plant layout, cartography of the factory, physical mock-up;
- catalogues, patents, general documents of the manufacturer;
- handbooks, specialized reviews, World Fair reports;
- private industrial files or public funds (J series of the French departmental records);
- technical and industrial public files (M and S series of the French departmental records, public records);
- interviews, anthropological and sociological investigations;
- …

Sometimes, the physical object is in a so advanced degradation state that digitalization will be without interest or impossible as the object does not exist any more in the industrial plant. That's why, if additional capitalized knowledge is sufficient, it will be possible to carry out an extrapolated virtual reconstitution but sure that will not be authentic.

3.4 State B: the Digital Heritage Reference Model

If the object could have been modeled in a virtual form, the mock-up becomes a new object we can call: "reference model". Moreover, if environmental and associated knowledge are capitalized, then State B constitutes a new kind of file for conservatives: the "technical heritage work file“ (in French, we would prefer the wording "dossier d'œuvre patrimonial technique"; indeed, the French word "œuvre" gives more authenticity and value than the English word "work"). Centered on the virtual reference model, this file combines complementary technical data of the object, environmental data and also the social and economical context.

The Digital Heritage Reference Model is a new conceptual idea introduced by our team in order to sensitize to the add-in it provides.

Then, in order to be as functional as possible, this new patrimonial file will have to be on a digital and virtual form. But we mention that nowadays there are no recommendations for this kind of document that combine textual information, videos, 2D images, 3D mock-up, dynamic simulations, sounds, odors...

Moreover, multiple computational formats exist for constituting knowledge bases but few, even none, can integrate such different nature of data with hypertext. This format must be interoperable and easy to handle by any today systems and especially must be able to be preserved and understandable for the future generations.

3.5 Process B-C and State C

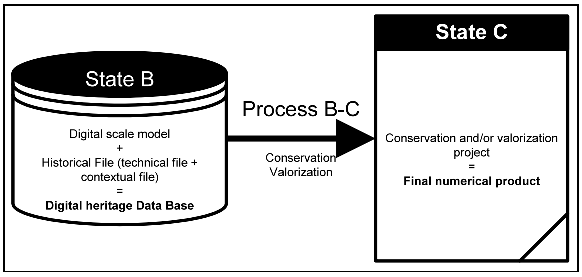

Fig. 9 - Second step of the process: B to C

Once the Digital Heritage Reference Model made up, it is possible to consider various finalities for the virtual object among which, we can distinguish:

- a patrimonial record;
- a restoration / a reconstruction;
- a didactic engineering use for students or by experts in order to use it as springboard for innovation;
- a museologic and scenographic valorization in a virtual form as 3D Web which can be assisted by Virtual Reality technologies in order to immerse the visitor in the system.

For last case, for instance in a valorization for Museums, several approaches can be developed. They can consequently fix objectives of State C:

- 3D+t modeling and/or knowledge management access;
- visualization in 3D Web;
- immersion in a system of Virtual Reality.

3D Web allows user to visualize 3D and 3D+t models of virtual objects on a standalone computer in Museum or at home.

One of the most thinkable purposes consists in transferring model in an immersion system intended for didactic finalities or Museums. Virtual Reality technologies are fully increasing and numerous solutions nowadays exist as well at a commercial level and at an experimental level. Many interfaces exist among which there are:

- forced feedback, pressure feedback;
- eyes tracking;
- stereoscopic vision;

- ...

It is important to notice that once the final state C is defined, it is necessary to iterate with state A in order to take into account documents needed. Indeed, determining the State A document package is difficult as we do not know how the object and its context will be exploited. Consequently, the amount of work and the way of capitalizing and digitalizing knowledge will be a little bit different.

4. Example: the Creusot steam engine

Here is sum up one experimentation we did. The global process is not complete as long as we are regularly iterating with conservative needs.

However, it gives a preview of what can be done merging two communities: history and mechanical engineering.

The figure 10 on the next full page shows the global process followed according to the points explained in part 3 of this communication.

4.1 Background

In 2000, the history of a steam engine currently "stored" in the warehouses of the Ecomusée du Creusot had begun. Its life was recalled and also its memberships, its functions...

In order to complete the steam engine know-how and as the machine cannot any longer operates and that all components are dismantled, a modeling of the steam engine operation had begun in 2003. It resulted in its kinematic diagram for illustrating its basic operation (piston engine, rod, and wheel) and it produced a numerical model at scale 1:1 of the steam engine. The dead machine was operating again but without dust!

Nowadays, we are working upon a didactic presentation for the Museum.

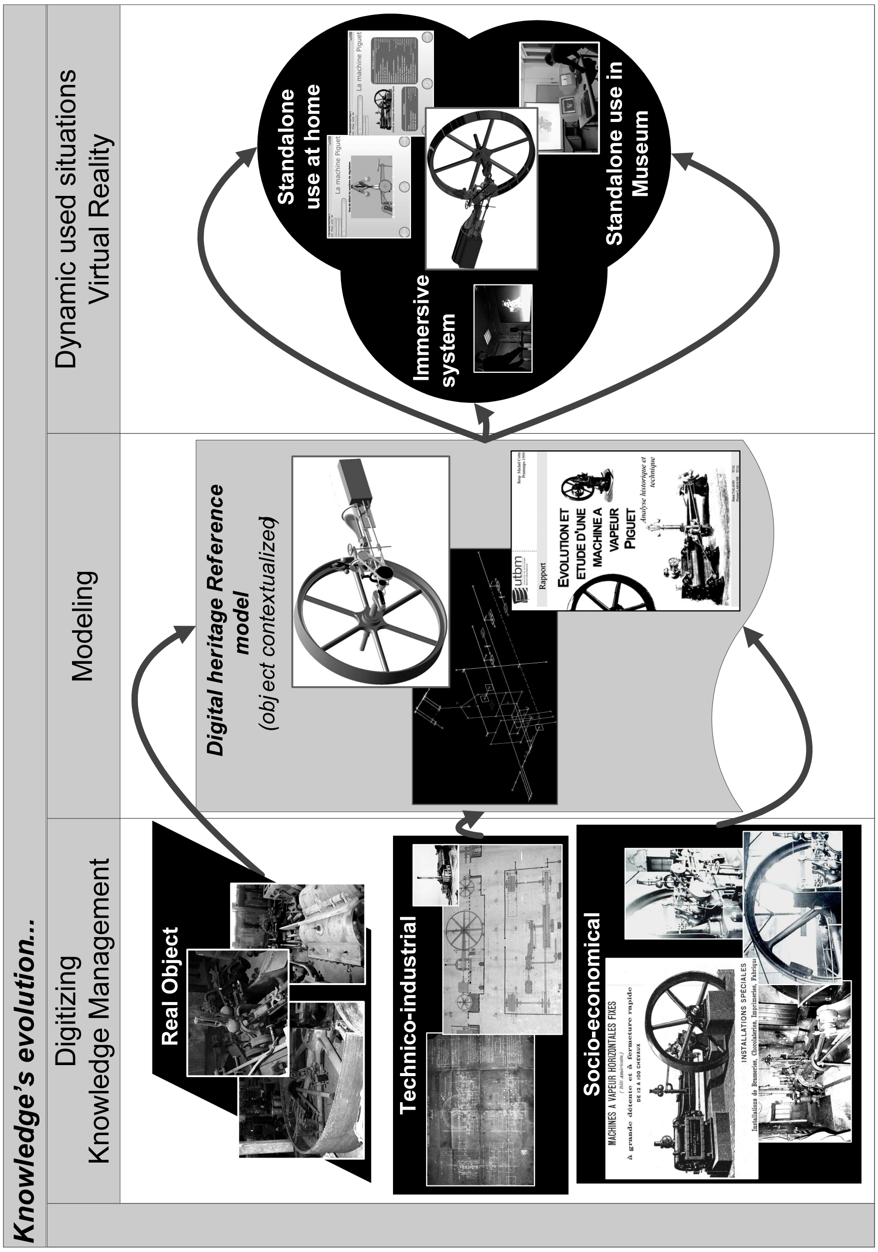

Fig. 10 - The global methodology used for the Piguet steam engine

4.2 Knowledge capitalized

This steam engine was originally built by the Piguet Company located in Lyon, France.

In 1898, the machine was installed with four other similar steam engines in the factory of Fontvieille at Monaco (figure 11). Coupled to dynamos, they produced electricity for the "Monegasque Company of Electricity". The power station plant capacity was 1680 kW, the team for the electrical department included 40 employees and the price of kWh was 1.70 gold francs.

But the maintenance of the steam engines was expensive and the boilers required large quantity of raw fuel, it was necessary to renovate the Fontvieille station with more efficient generators. Also considered as highly polluting for the landscape of Monaco bay, the four steam engines were replaced in 1917.

Fig. 11 - The Fontvieille power plant

One of them was moved to France, in Moulins. It was used as a generator for a mechanical sawmill. It remained 13 years there. In 1930, the steam engine was again repurchased by another sawmill and it is at La Roche-en-Brénil that the machine will finish its life where it provided mechanical energy for five saws.

But the low cost of electricity and the high cost of the steam engine maintenance brought its stop in 1972.

In 1977, the Ecomusée du Creusot decided to purchase it in order to preserve it. But since the factory was built when the steam engine was installed, it was impossible to dismount and move the machine without destroying the building itself. For economical reasons, the steam engine was condemned to spend its entire life in the sawmill.

But, in 1994, the sawmill decided to destroy the steam engine building; then, the museum dismounted the machine and stored it dismounted in its store (figure 12).

Fig. 12 - The machine in the Museum reserve

4.3 Characteristics of the studied machine

This machine is a steam engine from the French manufacturer Piguet. Its specifications are:

- horizontal machine;
- right-hand machine;
- plane drawers;
- one cylinder;
- condensation type and variable relaxation.

As seen before, the steam engine had been in operation from 1898 up to 1975. As the machine is nowadays dismounted, only the catalogue of the Piguet Company gives its dimensions: including rod, crank, piston, inertia wheel, it measures 4.40 meters width, 6.40 meters length and 4.20 meters height (figure 13). The piston engine measures 400 mm length for a stroke of 800 mm. That's why its official reference is 40X80 TP. Its first function was the energy production (mechanical and electrical).

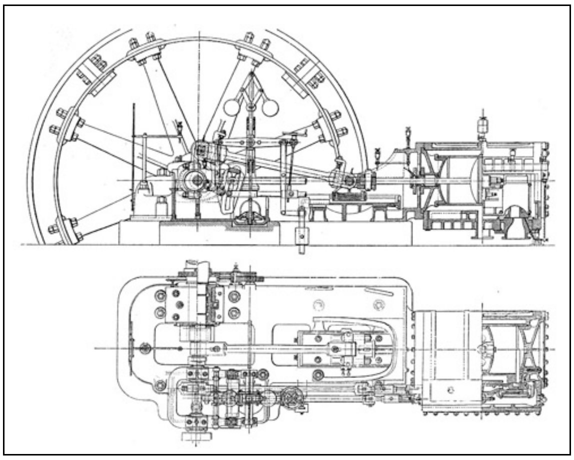

Fig. 13 - 1886: Steam engine from Piguet catalogue.

4.4 Modeling

As specified in the global process description, the first step is to study the movements and the kinematics. Three groups were identified:

- the power group;
- the regulator group;
- the control group.

After measuring minimal technical dimensioning, it was possible to reconstitute kinematics in a wireframe numerical model (figure 14). All modeling were done with the program Catia V5R8 from Dassault System.

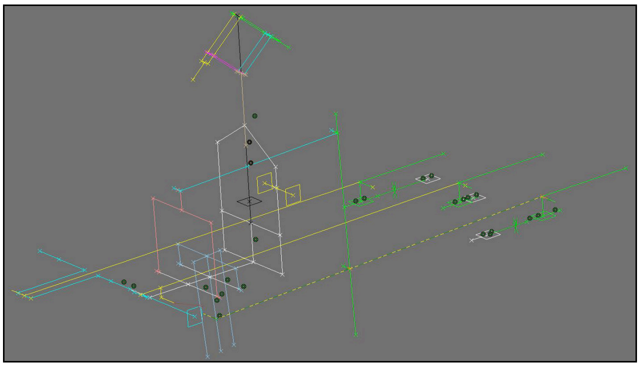

Fig. 14 - Kinematic skeleton model

After validation of the model, the components were modeled in 3 dimensions (figure 15).

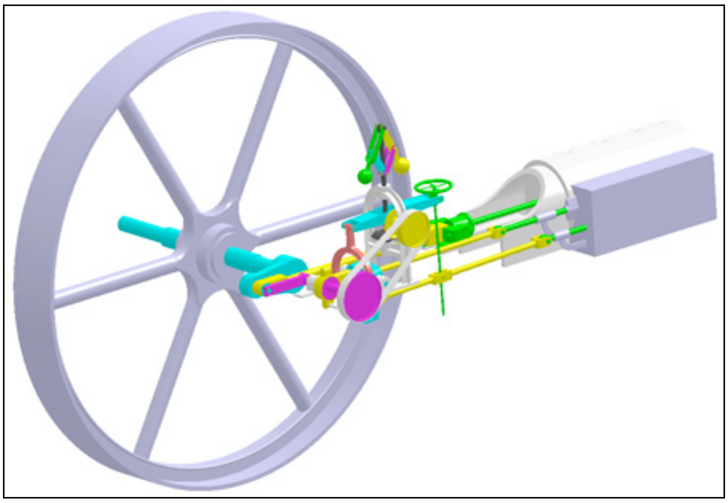

Fig. 15 - Steam engine with functional colors

4.5 Valorization

For operating a steam engine, hot steam is necessary; to produce such quantity of steam at high pressure, a boiler is required. In the past, there were many accidents with boiler explosions. As using steam engine and all the adding components is dangerous for public, the digital mock-up simulations have to take their place in Museum. In this spirit, it has been projected to create a steam engine Museum with, of course, mainly virtual machines.

Nowadays, the museum project is not yet a main objective and at first, a didactic presentation of the Piguet steam engine has to be produced. It can be used in standalone inside the Museum by every kind of public (figure 16). It:

- presents the project background;
- describes the machine history;
- explains the system operation.

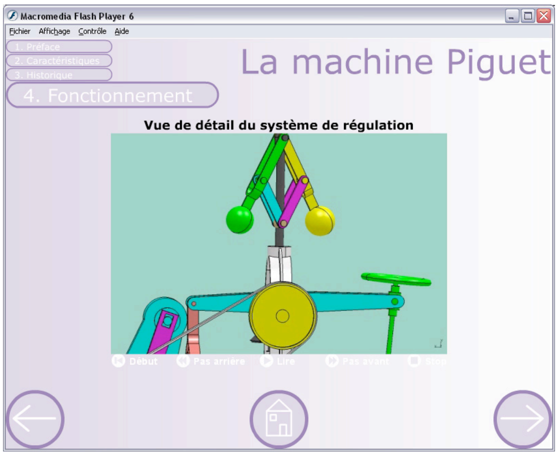

Fig. 16 - Didactic Flash application of the steam engine

Moreover, we made experimentations in museum conditions but at the laboratory using a virtual reality room. Among a non-technical public, we have immersed them in the initial dynamic situation of use in order to determine how they fill the use of virtual reality technologies upon old machines.

In order to compare the added value of virtuality upon reality, the experience is a compound of:

- a classical exposition with images, videos, textual explanations and a machine physically stored but not operating (for security reason),
- and a virtual room. Here, the same machine is presented but only virtually (figure 17). It is simulated by Catia V5 in real time with passive 3D vision. Visitors can manipulate the simulation in the space thanks to a 3D mouse.

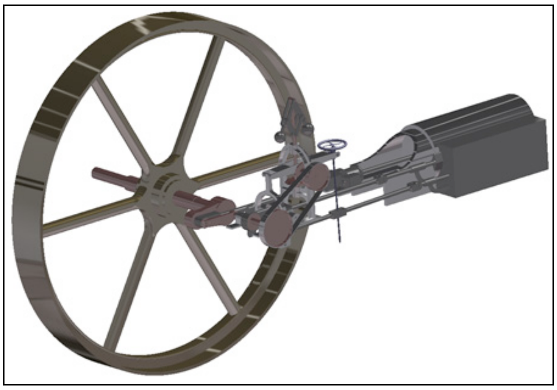

Fig. 17 - Steam engine with nearly true colors

The sample is between 10 to 70 years old. A real difference appears between young visitors and others regarding their feeling and their ability to use virtual reality technology: obviously, children feel it easy with the use of virtual interface as the 3D mouse. Globally, everybody agree to consider that the virtual can not replace physical machines. However, instead of a "dead" machine, manipulating a virtual simulated model can help:

- for the visitor to take the role of a worker on the machine,
- to understand the machine in operation as its components are moving,
- to see the complete plant,
- to go above, below and throughout the walls; which means view points that are not in the habit,
- to see part details by zooming; for example very small elements or normally hidden ones,
- to change colours, or make transparency or cross sections so as to highlight the different components.

However, virtuality is not ideal and some major issues remain: need avatars, can not be touched…

4.6 Knowledge complements and future works

In this example, the Piguet steam engine history has been studied: it rules on it from its first use in 1898 until its dismantling and its storage in the Eco-Musée du Creusot-Montceau in 1994. Moreover, thanks to CAD software, a mechanical approach of the system has been designed and simulated.

However, next works will consist in contextualizing more precisely the machine over its multiple lives. A machine is designed, build and used for a determined goal; it is settled in a workshop and put in correlation with other machines in the factory (see figure 18). Studying this setting up and the links between machines and humans can reach to a restitution of the working situation model.

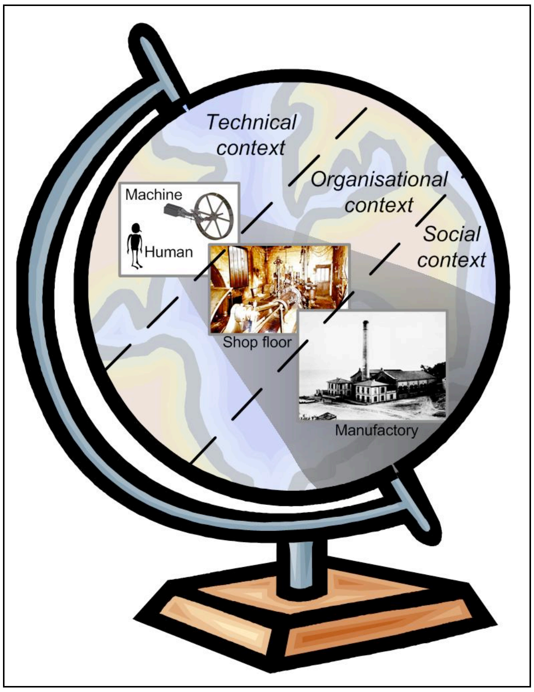

Fig. 18 - The industrial plant fitting

Later, thanks to virtual technologies, the global environment could be designed in order to analyze, simulate and correlate it with the historical hypothesis. Moreover, in the virtual model, it could be possible to attach knowledge & information by using the hypertext links: machine drawings, manufactory drawings, patents, images, sounds, videos… The objective is to create and to structure data in an informational model that would be a representation of the machine in one or several considered periods. Obviously, all the informational levels described by figure 15 must be inquired and put in correlation together.

5. Conclusion

The global process given in this communication is the first one that merges two communities: Mechanical Engineering and Social Sciences. Actually, it represents a new investigation way for technical and scientifical museums; it gives a new dimension for heritage allowing the use of Virtual Reality tools for other application cases than architecture... The main and strong advantage of the method is that it gives a scientifical accuracy to the produced images.

But, finding common vocabulary is not so easy and in addition, culture and heritage, practices differ from one country to another.

However, France would like to continue in this way: the idea of using engineer tools and methods for technical heritage and the proposal method have been found with open arms by few international scientific Museums.

The example given previously can be considered as a simple experimentation as the Ecomusée du Creusot is the French national site for old files and reports about steam engines and boilers. Indeed, the city of Le Creusot was the heart of the metallurgic industrial revolution during the two last centuries with the famous Schneider Company.

Recently, we made one other experimentation with a salt washing machine with firstly a laser digitalization. Moreover, instead of having 25 CAD components as for the Piguet steam engine, the machine includes approximately 550 CAD components and was a fully home-made machine leading to mechanism understanding but inducing a more difficult modeling.

Although it was not at all foreseen, the team noticed that all the analysed examples were from the 19th and 20th centuries. In fact, there is a real divergence and barrier when comparing the conservation and valorization methods before and after the 2nd industrial revolution. The question is what were the mechanisms used before the 19th century? It must be reminded that in the past, only natural energy was used such as water, wind, animals or humans; but nowadays, controlled energy is the basic with nuclear, gas, fuel, or even coal… The transition corresponds to the period when industries have widely mechanized the factories; moreover, it must be noticed also that it is the time when the world fairs appeared. Concerning industrial heritage, capitalization tools have also to be customized to the knowledge and the concerned machines. Consequently, methods and tools commonly used in modern sciences and techniques must ensure their own role.

Thus, it is necessary to review the understanding methods for old technical objects as Jocelyn Jocelyn de Noblet illustrates it: "We are in 1910, a 70 years old engineer is visiting the Eiffel Tower in Paris with his young son. Taking into account the monument as an example, he explains him what is the material resistance, a mesh… Nowadays, the same engineer with his young son are visiting the Millau Bridge in France, but the engineer says to him: "I would explain it to you when you will be older as it is a little bit complicated." [8]

Knowledge Management is become a necessity for future generation…

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